Reply to Review #2

We would like to thank the reviewer for the positive comments, which help to clarify certain points in the manuscript.
We provide a point by point answer to the comments below, comments by the reviewer in blue and our answers in black.
In addition, we realised that while in the figures it says z=XX cm, the text states z=XX mm. We have unified these occurrences to always use cm.

- The data set could also be useful for model inter-comparison projects (e.g., a case for the next International Cloud Modeling Workshop) and evaluating different subgrid turbulence-microphysics interaction schemes. The authors should consider highlighting that in the manuscript.

Thanks for pointing this out! We have expanded the “Future use” section as follows:

Thus, we believe that this data will not only be useful for studying processes as outlined above, but will also be useful as a test bed for several model studies, both on individual level and for model inter-comparison projects. Additionally, it can be used to validate simulations.

- L35: The authors could also mention the CloudKite measurements as another unique way to collect high-resolution data for entrainment-mixing studies.

Thanks for the suggestion, we have included a sentence on CloudKite as well.

“Similarly, tethered balloon systems using helikites like the CloudKite (Schlenczek et al., 2026, Stevens et al., 2021) can provide a platform for highly resolved observations. However, as ground-anchored systems, they cannot actively target regions of interest horizontally and are limited by payload and maximum ceiling.”

- L82: It's confusing to see uncertainties reported as % +- some value. Do you mean '1.5% |v| + 0.03 m/s' here?

Yes, the measurement uncertainty equals ± (≤ 1.5 % of the measured value + 0.03 m/s), thus, e.g. for a flow speed measurement of 1m/s it is ± 0.045m/s.
We adapted:
“... with an uncertainty of ± (≤ 1.5 % (measured value) + 0.03 m/s)”

- L179: Can the authors add a paragraph describing turbulence statistics in the measurement section? It would also be helpful to show PDFs of temperature, water vapor, and velocity fluctuations (and their moments) at different vertical locations in the mixing zone.

Direct measurements of fluctuations are unfortunately not available (partly due to lack of needed instrumentation, e.g. for water vapour fluctuations or incompatibility to use instrumentation for fluctuations together with the droplet stream).

The general turbulence characteristics of LACIS-T have been described in detail in Niedermeier et al. (2020), who also show the ability of the OpenFOAM setup to reliably simulate the flow characteristics. Therefore, we expect the model results to properly represent the fluctuations also in our experiments. We added to the manuscript in Sect. 4.1:

“Turbulence characteristics
Measurements of fluctuations to determine the turbulence statistics of the flow are unfortunately unavailable for this set of measurements. However, turbulence characteristics of LACIS-T based on observations (and simulations) are described in Niedermeier et al. (2020), who have also shown that the OpenFOAM setup is able to reproduce the characteristics in its simulations. Thus, we provide some information on the turbulence characteristics in Sect. 5.2.”

In Sect. 5.2 we added:

“Figure 7 shows some of the simulated turbulence statistics (eddy dissipation rate (ϵ), turbulent kinetic energy (TKE), Taylor microscale, and Taylor Reynolds number) in the mixing plane of LACIS-T.”

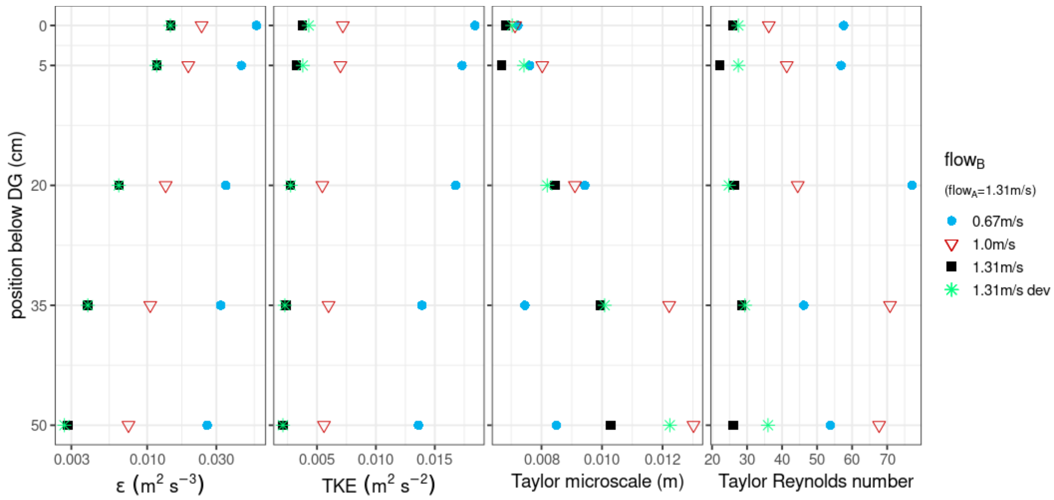

Figure 7. Turbulence statistics versus position below the droplet generator as simulated with OpenFOAM, from left to right: eddy dissipation rate (ϵ), turbulent kinetic energy (TKE), Taylor microscale, and Taylor Reynolds number. Different colours and symbols denote the different flow settings.

As can be seen from Fig. R1, with increasing shear, the velocity fluctuations become stronger (increasing widths of distribution), and thus, TKE (c.f. Fig. 7). Also the mixing between the two air streams become stronger with increasing shear, one could sense a small decrease in width of the RH and temperature distributions, which however, are also impacted by a less symmetric flow with increasing shear. The somewhat strange behaviour of TKE, Taylor microscale, and Talyor Reynolds number for the 0.67m/s at 20cm and 1.0m/s at 35cm points might be caused by formation of a standing vortex or by effects from the slit between the two air streams at the point where they combine (which contains the aerosol inlet).

We furthermore added to Sect. 5:
“ Model simulations are run for all three flow settings (no shear/low shear/high shear) resembling the measurements on the 16-02-2022, 01-03-2022, and 02-03-2022. One additional simulation for the no shear case was run, where a slight deviation of 0.05m/s was imposed on the flow speed in channel B, to identify whether a potential deviation in flow speed during the measurements would have a noticeable effect on the turbulence characteristics and potentially on the droplet size distributions.”

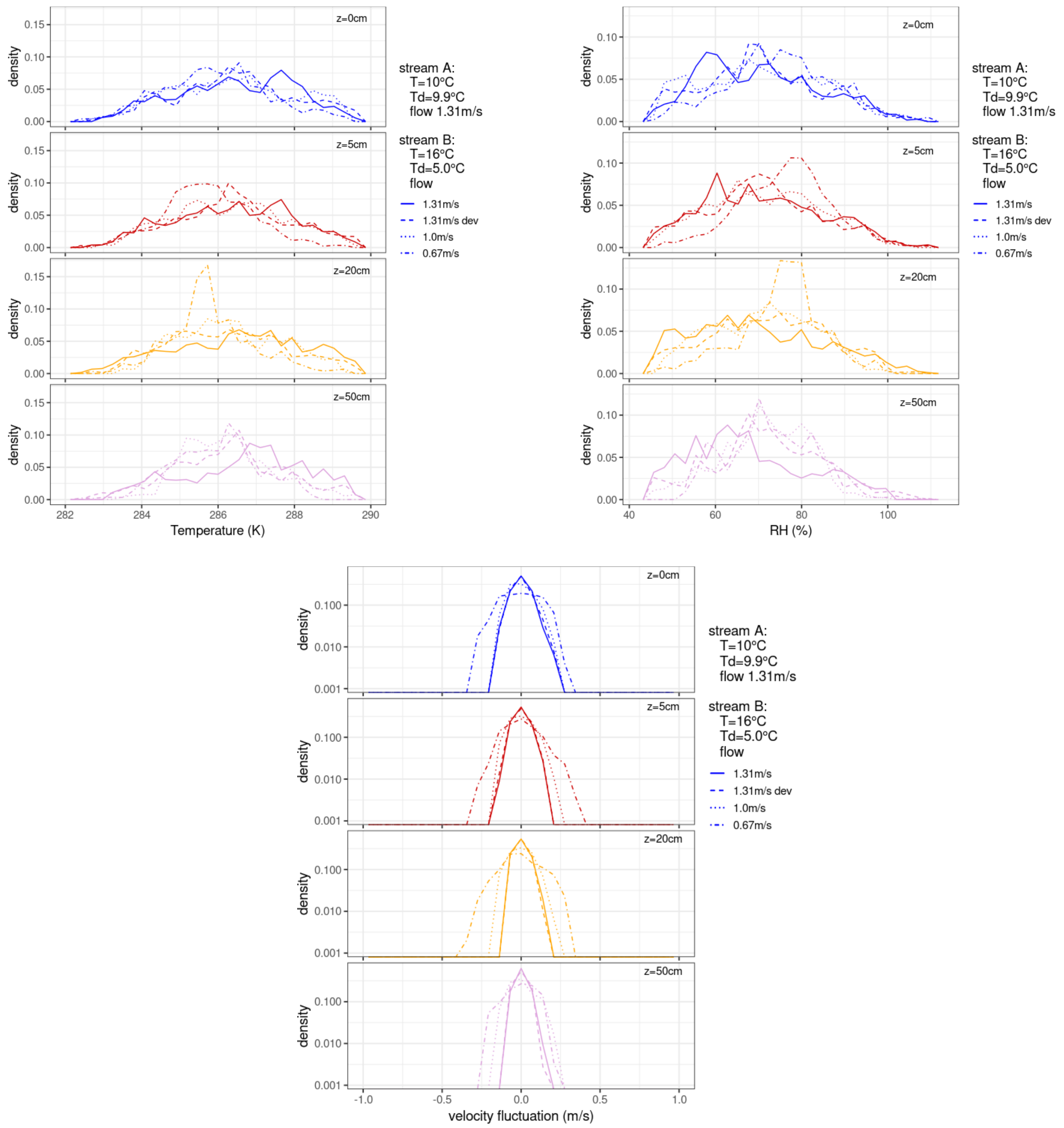

Fig. R1: Density distributions of simulated temperature (upper left), relative humidity (upper right), and velocity fluctuations in z-direction (bottom), for all simulated flow speed settings (see different line styles) and at all simulated positions below the droplet generator (z-position indicated in the panels).

- L204: The sentence starting with 'However' seems abrupt. I can't see any statement above that you are contrasting. Is there something missing?

Thanks for the observation, we changed the “However” to
“It has to be noted that”

- Please discuss the assumptions underlying the simulation setup in more detail. For example, does the condensation growth model include the curvature and solute effects (or a pure water drop assumed)?

The general model setup is described in detail in Niedermeier et al. (2020), we make the connection more explicit in the revised manuscript. A brief addition here to the original manuscript:

For the simulation of the non-isothermal flow the conservation equations for mass, momentum, energy, and water vapour content are solved (using the adapted version of OpenFOAM's "chtMultiRegionFoam" solver). For simulating turbulence we employ the dynamic k-equation Large Eddy Simulation model.
For the particle phase: The droplet activation is calculated according to Köhler theory (i.e. including curvature and solute effects, however in our experiments we use and simulate pure water droplets). Given the size of the droplets in our experiments, the curvature effect on the particle growth becomes negligible.

We changed the manuscript accordingly:
"For simulations of non-isothermal and humidified flows, an adapted version of OpenFOAM's "chtMultiRegionFoam" solver is employed, which solves the conservation equations for mass, momentum, energy, and water vapour content. Turbulence is simulated using the dynamic k-equation Large Eddy Simulation (LES) model. For further details see Niedermeier et al. (2020). To simulate particle (i.e. cloud droplets) dynamics, an Euler-Lagrange approach is used. This tracks individual particles along their trajectories through the simulation domain. Droplet growth (including Köhler theory) and evaporation are both resolved in the current model version, with a two way transport of water vapour between the fluid and particle phase. Additional growth by collision and coalescence and ice microphysics are not (yet) implemented."

Additionally, we detected one error in the introduction of the OpenFOAM model, in our case, we solve the compressible (not the incompressible) Navier-Stokes-Equations. We changed the text accordingly.

- L227-229: Growth by drop collision-coalescence - But the droplet concentration distribution (left plot in Fig. 6) shows hardly any change for the large droplet tail concentrations. Normalized distributions (PDFs) can be misleading when comparing tails if the mode decreases more than the tails.

True, this is why we chose to include both – the dN/dlogDp and the normalised (density) plot here. As stated in the following of the lines you mention, the most part of collision-coalescence is possibly happening in the first few centimetres downstream the droplet generator (thus between z=0mm and z=50mm), and here the shift in tail is clearly visible. We agree, that further downstream the effect is hardly visible, also given the lower droplet number concentrations, only few counts would be expected. Thus, a more statistical analysis would be needed, which is hard to convey in a size distribution plot. However, from 0cm to 5cm (blue to red curve) the broadening towards larger sizes is clearly visible.

- L234: As I mentioned earlier, it would be very useful to discuss the turbulence statistics relevant for collision-coalescence (e.g., turbulent dissipation rates, Taylor's micro-scale Reynolds number, Stokes number, PDFs of velocity fluctuations, etc.).

See answer to the turbulence characteristics above. In addition, we added a sentence in the section on particle observations (Sect. 4.2):

“The mean Stokes numbers for the droplets are for all settings < 0.053, calculated following Devenish et al. (2012), using the measurements to retrieve the droplet characteristic inertial response time, and the simulations for retrieving the Kolmogorov timescale.”

References:

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